A Golf Course Bibliography

By

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Golf is a multimillion dollar business that requires the use of enormous amounts of pesticides and fertilizers to maintain the well manicured course that is expected by those paying to play. Each course, averaging between 124 and 180 acres (Beard, 1982; Watson, 1990) is managed by a superintendent that is educated in the art of turfgrass maintenance. The turfgrass industry includes not only golf courses but other sports playing fields and the home lawn. Of this huge industry, golf only represents approximately 6% of the total money involved (Cockerman, 1985; Watson, 1990). Different regions of the country require specific management strategies due to differences in climate, geology, and hydrology. Therefore, superintendents have their own strategies for their course that was developed from experience and various other sources such as the scientific literature.

Public concerns for the environment and increasingly stringent water quality restrictions have led to the idea of best management practices (BMPs) for golf courses. Krivak (1978) conceptualized BMPs for agricultural crops. The BMP concept consist of five basic goals: 1) decrease the offsite transport of pesticides and nutrients, 2) control the application of these chemicals, 3) decrease the total chemical loads, 4) use both biological and mechanical soil and water conservation plans (SWCPs), and 5) educate both the managers and the public about the relationship between environmental issues and golf course management (Balogh and Walker, 1992).

However, research published to date lacks the ability to provide BMPs to golf course superintendents. There are only a few attempts at such a task (Leslie and Metcalf, 1989; Walker, 1990; USDA-ARS, 1988a; USDA-ARS, 1988b). The project at the Ocean Course on Kiawah Island is an effort to bring together many of facets of environmental research into a single holistic approach to providing plausible management strategies. Another study currently being undertaken at Clemson University is a comprehensive survey of all golf course managers in South Carolina. Compilation and comparison of each of the various strategies will hopefully provide a base to build best management practices for superintendents.

Balogh and Walker (1992) have outlined the potential detriments of construction and management of golf courses. Probably the most important concern of the present is the potential for contamination of surface and groundwaters with sediment, nutrients, and pesticides (Cooper, 1987; Grant, 1987; Klien, 1990; EPA, 1986; EPA 1988; Keeney, 1986; Petrovic, 1990; Pratt, 1985; Pye *et al.*, 1983). Continuous use of pesticides in turfgrass management strategies may also lead to an increased resistance by the target organisms (Potter and Braman, 1991). Obviously, there is the concern of possible negative impacts on nontarget organisms by chemical management strategies (Kendall *et al.*, 1992; Stone and Gardoni, 1985a; Stone and Gardoni, 1985b; Stone, 1979). The U.S. is not the only place where public awareness has brought this to governmental agencies attention. Japan has begun setting standards for maximum allowable pesticide residues found in golf course effluent (Tsuda *et al.*, 1992). In order to maintain the lush green carpet of turfgrass, an extremely large quantity of water is used. The push for water conservation has resulted in increased utilization of secondary treated sewage effluent for irrigation (Roberts, 1989; Payne, 1987). Effects of golf courses on the precious wetlands of the U.S. have also been of public concern. Developers and managers have also realized their importance (Dye, 1989; Peacock, 1990; Salvesen, 1990). With the increasing cost of "after the fact" mitigation, better management practices that prevent some of these problems are being evoked. Slowly, scientific research on environmental impacts of golf courses are being published (Leslie and Metcalf, 1989; Petrovic, 1990; Walker, 1990). However, much of the past and present research presents only a small portion of the whole picture. There is a great need for more comprehensive studies and literature reviews (Balogh and Walker, 1990; Beard, 1982; Beard, 1973; Madison, 1982). Computer expert systems for planning turf management such as TURFPLAN appear to work well for low maintenance applications, but fall short of designs of human experts for high maintenance turfgrass such as golf courses (Liu *et al.*, 1991).

In the battle to establish management strategies for golf courses, there have been two basic approaches. Some claim that the total acreage maintained (Smolen, 1984) is a better indicator of possible risks as opposed to the obvious quantitative total volume of chemicals applied. This partly stems from the fact that the total annual use and number of pesticides or fertilizers applied varies among courses and within courses (Beard, 1982). There are three basic management practices concerned with golf courses that raise environmental issues. Pest control involves the use of a wide range of chemicals including insecticides, herbicides, and fungicides. Plant growth regulators (PGRs) may also fall into this category because of their basic chemical makeup. An alternative to the use of pesticides that has some promise is that of biological pest controls (Myers *et al*., 1992). The cultural practices of fertilization and irrigation represent the remaining two that gain public attention. Both have been shown to affect pest populations and subsequent damage (Beard, 1973). Nitrate (NO_3) originating from cess pools, septic tanks, animal and human wastes, and fertilizers (Keeney, 1986) is one of the most widespread groundwater contaminants (Pye *et al*., 1983). Finally, irrigation and drainage practices directly affect pesticide and nutrient applications in turfgrass management (Biran, 1981; Colbaugh, 1985). One can now see that all management decisions are interrelated and codependent.

Probably foremost in the mind of a superintendent when planning pesticide management is the safety of the workers and golfers. A few studies have made attempts at finding safe levels of dislodgeable residues and the time required post-application to achieve them (Goh *et al*., 1986; Harris and Soloman, 1992). The results indicate that for most pesticides used, there is little risk involved with reentry to a treated site. A method for quantifying airborne loss of pesticides was described by Jenkins *et al*. (1991). The only practical method for preventing serious damage of turf by insects is the use of insecticides (Potter and Braman; 1991). Insecticides may have indirect effects that counteract or cause a more serious problem. The have been shown to adversely affect earthworms causing thatch buildup (Randell *et al*., 1972).

Populations of predators and parasitoids in the soil may also be diminished causing some secondary outbreak (Cockfield, 1983). Conservation of these natural enemies should factor into pesticide selection. Certain commonly used herbicides also pose the threat of causing phytotoxicity and decreased turf quality. The timing of applications to sensitive turf species such as creeping bentgrass is very important (Shim and Johnson, 1992). Frequent use of select fungicides may enhance some nontarget diseases, while the nontarget benefits appear to be turf species dependent (Dernoenden and McIntosh, 1991). The use of plant growth regulators for golf course applications are limited due to the potential for turf damage and inconsistent results (Christians, 1985). Some PGRs have been found effective if used in areas that are hazardous for trimming or mower operation (Fry, 1991). Fry also reported that glyphosate (0.6 kg/ha) caused unacceptable phytotoxicity. Johnson (1992) reported variations in effects, from slight to moderate turf damage by two PGRs. Recovery was complete by 10 weeks. This would appear unacceptable for the golf industry that is forced to maintain turf at the highest quality possible. Hence, more research is needed to pronounce sentence on PGRs. Outside of these pure turf management concerns, the superintendent must also be environmentally sensitive and be concerned about pesticide runoff. Binding to thatch, which increases retention time for degradation processes, is reported to diminish the amounts of pesticides in runoff to safe levels in receiving waters (Miles *et al.*, 1992; Potter and Braman, 1991; Watschke, 1990). Enhancement of natural phenomena is a management technique that is receiving more attention.

Cranshaw and Zimmerman (1989) reported effective results when using nematodes to control turfgrass scarabs. They also go on to point out problems associated with this practice such as: availability, storage, cost, handling, and reliability. Dollar spot, a common disease found on golf courses (Smiley, 1983) was effectively suppressed with applications of compost (Nelson and Craft, 1992). This research was based on the fact that composted substrates hold disease-suppressive properties due to their microbial content (Hoitink and Fahy, 1986). Again, more field research is needed to evaluate the usefulness of biological control methods for use on golf courses.

Fertilizer management poses some concerns similar to those associated with pesticides. Petrovic (1990) summarizes and reviews the literature dealing with nitrogenous fertilizer usage. Nitrogen and potassium fertilization of turfgrass has been linked to resistance to stress conditions brought on by disease, drought, or human foot traffic (Beard, 1973; Cook *et al.*, 1983; Markland, 1969). The distribution of nitrogenous fertilizers is normally studied as a series of components rather than a complete system. Even though conclusions are limited to a certain cultural and geological situation, Starr and DeRoo (1981) attempted to study all of the components. Atmospheric loss of nitrogen may occur via NH_3 vaporization or denitrification. Ammonia volatilization can be decreased by irrigation (Bowman *et al.*, 1987), decreased thatch content, and the use of time-release nitrogen pellets (Nelson *et al.*, 1980). The process of denitrification and its effects are limited in the literature (Mancino *et al.*, 1988). Controlled-release or time-release fertilizers are used commonly on turfgrass (Turgeon, 1985). A study of reactive layer coated (RLC) nitrogen (Peacock and DiPaola, 1992) yielded results indicating that their effectiveness depends upon the thickness of the reactive layer coating. A similar study involving controlled-release potassium (Snyder and Cisar, 1992) looked at the coating material’s effect on potassium release. Sulfur-coated (SC) released potassium too rapidly, while the converse was true for resin-coated (RC) potassium. All other sources of potassium tested had favorable characteristics. As with pesticides, leaching and runoff are also a concern. Leaching is highly influenced by: soil texture, nutrient source, rate and timing of application, and irrigation/rainfall (Petrovic, 1990). It is thought that because a turfgrass ecosystem results in soils with high infiltration capacity, runoff is seldom a problem (Gross *et al*., 1990; Gross *et al*., 1991).

Obviously a big factor in the previous discussions, water, via rainfall or irrigation, must be seriously considered when formulating a management strategy. Organophosphates and carbamates applied in a granule form require immediate irrigation so as to reach the target organism as well as decrease the chances of nontarget exposure (Potter and Braman, 1991). Just as adequate fertilization enhances turfgrass quality and resistance, so does maintaining the appropriate soil moisture (Couch and Bloom, 1960; Sugimoto *et al*., 1990). A chronic study (3.3 yrs) monitoring the soil quality of turfgrass irrigated with secondary treated effluent was conducted by Mancino and Pepper (1992). Soil salinity, pH, Fe, K, Na, and P levels all increased. Addition of calcium sulfate or sulfur can be used to bring the sodium levels back to normal. The excess phosphorous could be accounted for by decreasing P added in the form of fertilizers. No effect was recorded on the levels of total organic carbon (TOC), total nitrogen (TN), or total aerobic bacteria. So it seems that irrigation with effluent may require additional management for some things while eliminating others. Nus and Sandburg (1991) point out that irrigation with effluent must be closely monitored. Phytotoxic chemicals such as herbicides (eg. atrazine) may be present at levels to cause chronic problems.

In conclusion, much work still has to be done in order to present golf course superintendents with a “cookbook” approach to pest management. An interdisciplinary team consisting of superintendents, agronomist, environmental toxicologist, and chemist are needed to review past and current strategies. From this intensive cooperation, future research and strategies may be formed.

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